NATURAL INTERSPECIES GENE-FLOW PROMOTES ADAPTATION TO CLIMATE CHANGE IN LONG LIFE SPAN PLANT SPECIES

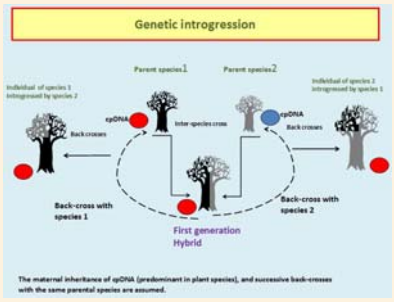
Roselyne Lumaret [1], Michael Staudt [1], Jean-Michel Leong Pock Tsy [2], Pascal Danthu [2]

[1] CNRS-UMR 5175, Centre d'Ecologie Fonctionnelle et Evolutive, 1919 route de Mende, 34293 Montpellier Cedex 5, France
roselyne.lumaret@cefe.cnrs.fr ; michael.staudt@cefe.cnrs.fr
[2] CIRAD, URP Forêts et Biodiversité, BP 853, Antananarivo, Madagascar, and Campus de Baillarguet, 33398 Montpellier Cedex 5, France
leong@cirad.mg ; danthu@cirad.mg

Introduction

The integration of foreign genes into a recipient species' gene pool as the result of interspecies hybridisation followed by hybrid backcrossing with a parental species, *i. e.*, genetic introgression, has repeatedly been reported in species that have recently colonised a new habitat. It is considered as an evolutionary important process potentially contributing to adaptation to new environmental conditions (e.g. climate change).

In long life span species characterized by low generation replacement, interspecies genetic introgression may be a more effective adaptive process than the mutation fixation which is slow.



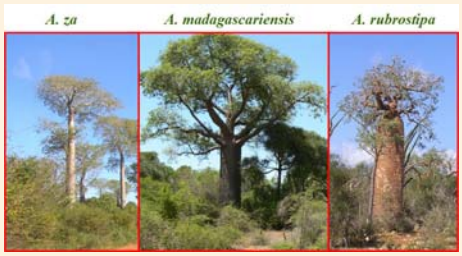
Objective:

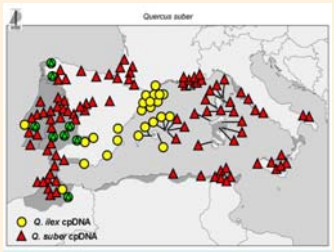
The geographical distribution of genetic introgression and the ecological conditions favouring interspecies gene flow were assessed in a couple of distantly related Mediterranean oaks, *Quercus ilex* L. and *Q. suber* L., differing substantially in their ecological niche, and in three Malagasies baobab species (*Adansonia za*, *A. rubrostipa* and *A. madagascariensis)* distributed along a strong gradient for humidity. In both case studies, the species showed partial overlapping ranges. Ecophysiological characters related to climate conditions (more particularly to drought) were compared between genetically introgressed and non introgressed individuals to identify new adaptive characteristics which may be related to genetic introgression.

Materials and methods

Chloroplast DNA (cpDNA) restriction fragment length polymorphisms (PCR-RFLPs) and variation at 10-12 nuclear microsatellite loci were analysed in populations covering the range of each species. When observed, morphologically intermediate individuals were also analysed.
The chlorotypes characteristic of each species were identified using allopatric populations as reference. The rate of cpDNA exchange was directly estimated as the frequency of chlorotypes belonging to the opposite species. Interspecies nuclear introgression was based on individual admixture rates using a Bayesian approach with no a priori species assignment, and on maximum- likelihood (ML) method, using allele frequencies in the allopatric populations of each species as controls (Lumaret *et al.* 2009; Lumaret and Jabbour-Zahab 2009).

In addition, the volatile organic compounds emissions (VOC) of *Quercus suber* and *Q. ilex* were analysed in two mixed stands contrasting in interspecies genetic introgression (Staudt *et al.* 2004).



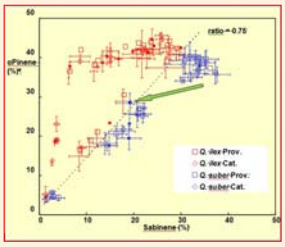


Geographical distribution of chlorotypes in cork oak.
The populations labelled with a green colour include chlorotypes of both oak lineages (modified from Lumaret *et al.* 2009).

Results

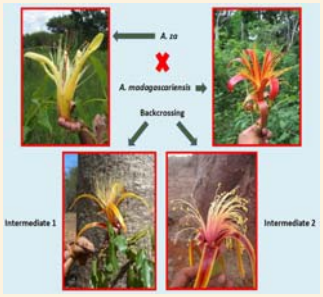
The complete replacement of *Q. suber* cpDNA by that of *Q. ilex* was observed exclusively in eastern Iberia with adjacent French Catalonia, and in a part of Morocco where the species grows at exceptionally high elevation and in cold conditions. No introgression for organelle genes was identified in the opposite direction. According to Bayesian assignment, approx. 1% of individuals had a high probability of being F1 hybrids, and bidirectional nuclear introgression affected approx. 4% of individuals in each species. Hybrids and introgressed individuals were identified predominantly in mixed stands (Lumaret and Jabbour-Zahab 2009).

Several individuals derived from recent hybridization, as shown on the basis of genetic markers, possessed rare VOC chemotypes, sometimes not observed in the parent species.



On the right, the figure shows the relative abundance of α-pinene against sabinene in foliar emissions from 39 *Q. suber* (blue symbols) and 46 *Q. ilex* (red symbols) sampled in French Catalonia (Cat.), an area with historical and substantial introgression, and in Provence (Prov.) characterised by moderate and recent introgression. A threshold ratio of 0.75 (dotted line) discriminates the two species fairly well. However, the green harrow indicates a *Q. suber* individual from Catalonia which was classified as *Q. ilex* according to VOC emissions.

In the baobabs, two main geographical areas of cytoplasmic and nuclear introgressions were identified in Madagascar island. These are indicated by green circles on the map which shows the present range of *Adansonia rubrostipa* (red color), of *A. za* (blue), and of *A. madagascariensis* (yellow). In both areas, the three species were concerned by interspecies gene flow, and revealed successive contact events which involved different species pairs. Morphologically intermediate individuals deriving from recent introgression were identified.



Discussion

In both case samples, genetic introgression was mainly observed at the margin of each species range, and was directly associated to species expansion. Genetic introgression was predominantly (but not exclusively) observed from the local to the invading species which was the pollen parent in the initial interspecies hybridisation. Complete introgression for organelle genes was observed exclusively in large specific geographical areas, likely reflecting historical introgression (Lumaret *et al.* 2009). The first results obtained from the ecophysiological comparisons between individuals from introgressed and non introgressed areas support previous theoretical predictions (Currat *et al.* 2008). According to the simulations, genes from the resident species involved in local adaptation should easily introgress the invading species if they do not conflict with the invading phenotype. Further physiological experiments are needed to confirm decisively this assumption. However, interspecies gene flow already looks to be a very promising process for adaptation to climate change in long life span species.

References

• Currat M. *et al.* 2008. *Evolution* 62: 1908-1920.

• Lumaret R. *et al.* 2009. PP. 25-32. In: Aronson J., Pereira JS, Pausas eds. *Cork oak woodlands on the edge: ecology, adaptive management and restoration*. Washington, DC: Island Press.

• Lumaret R. and Jabbour-Zahab R. 2009. Ann. Bot. (on line) Doi:10.1093/aob/mcp 149.

• Staubt M. *et al.* 2004. New Phytol. 163: 573-584.